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A TECHNIQUE FOR PRODUCING CALISTHENIC BEHAVIOR  
IN A RHESUS MONKEY\*

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## SUMMARY PAGE\*

### THE PROBLEM

A technique for exercises to counteract the effect of zero gravity on skeletal muscles in unrestrained monkeys during extended orbital spaceflight was explored. A rhesus monkey was reinforced with both food and food-associated stimuli for making a high-effort response continuously for 3 to 4 hours. Various manipulations of the frequency of food reinforcement and signals indicating the availability of food were used to evaluate the effect of each on the exercise response and associated behavior.

### FINDINGS

The technique satisfactorily maintained exercise for up to 3 hours. A 50-percent reduction in the density of food reinforcement reduced exercise response rates by less than 25 percent. Removal of a signal that indicated the nonavailability of food had no significant permanent effects but did lead to a small increment in the exercise response rate. Presenting signals similar to the one that indicated food availability merely confused the animal and drastically lowered the exercise response rate.

### ACKNOWLEDGMENT

Grateful appreciation is extended to Mr. E. C. Melvin for his assistance in conducting the sessions.

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\*The animal used in this study was handled in accordance with "Principles of Laboratory Animal Care" established by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences - National Research Council.

## INTRODUCTION

In the Orbiting Primate Experiment (3) unrestrained rhesus monkeys are to be placed into Earth orbit for an extended period of time. The monkeys will be required to perform various tasks for their daily allotment of food and water, one of which will be a high-effort exercise routine. The purpose of the present study was to explore one of many exercise techniques that might prove feasible for maintaining the physical health of a rhesus monkey.

Since no precedent existed for ascertaining an appropriate amount of exercise for a monkey, estimates based on human requirements were made. One of many human exercise programs proven adequate to maintain physical fitness was developed by the U. S. Air Force and is described by Cooper (1). He has recommended exercises that produce maximum aerobic work capacity. Although these exercises seem inappropriate for a weightless condition because of their reliance on muscle exertion against gravity, certain aspects allow a prediction of exercises that might be transferable to weightlessness. One aspect is that the exercise generally takes place for a continuous period of time, 15 minutes or longer, and the entire body is undergoing movement. Based on this characteristic, the present study was designed in an attempt to produce a response in the rhesus monkey that would involve movement of most of its skeletal muscles and continue for long periods of time. In addition, the task was to be transferable to a zero-gravity condition where the same principles should apply.

The animal was trained to extend its arms to a reasonable height above its head and then to bend down and reach its arms to a position near its feet. The methodology involved an observing response (4); that is, each time the animal performed correctly, the response would produce either a signal that food could be obtained by pressing a food button, or a signal that food could not be obtained. During the appropriate signal, a response on the food button produced food.\* The observing response became the exercise response since it involved so much effort. To insure continuous responding, the signal that indicated food was available followed a variable number of exercise responses. By decreasing the frequency of signals, removing the nonfood signal, and rearranging the food signal, an analysis of the exercise behavior was accomplished.

## PROCEDURE

### SUBJECT

221, a female *Macaca mulatta*, was the subject. She had been used previously in an investigation that required similar responses on fixed ratio (FR) schedules of food reinforcement. She was maintained at 81 to 91 percent of her ad libitum body weight during the present experiment.

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\*The observing response in the present study is actually a chain of responses. The animal has to make the response or food is never available. This paradigm differs from that of Wyckoff (4) wherein food becomes available independently of an observing response.

## APPARATUS AND METHOD

The experimental chamber was 40 inches high by 32 inches deep by 27 inches wide, had a metal grid floor, and was sound attenuated, temperature insulated, and vibration isolated. Speakers provided white masking noise and fans provided air circulation. A radio, tuned to a local music station, was on continuously at a high volume in the room containing the chamber. Recording and control equipment were located in a room remote from the experimental room. Entry to the chamber was gained by a sliding door in the front plexiglass wall. The rear wall contained four translucent plexiglass buttons, two of which were centered 3 inches from the ceiling and 6 inches apart. The other two buttons were centered on the lower portion of the wall 3 inches from the grid floor and 6 inches apart. These buttons are referred to as "keys" because of their similarity to telegraph keys. The keys were transilluminated from the rear by clear luminescent lights. Food and water hoppers were located above their respective buttons on the right-hand side of the rear wall. Figure 1 illustrates ZZ1 preparing to press the top illuminated keys. The food hopper and button are seen near the animal in the lower right-hand portion. The water hopper and its button are next to the food hopper. The house lights are seen on each side of the top. These were illuminated when an experimental session began and extinguished when a session ended. The animal was observed through a TV camera located in the ceiling of the chamber. General activity was recorded when the animal interrupted a beam of light projected across the middle of the chamber.

ZZ1 required no training on the specific response because of her previous history on these manipulanda. She was reinforced for each response at the start of the first session. Reinforcement was a 0.60-gram pellet of Purina Monkey Chow. The exercise response consisted of the simultaneous depression of the lighted pair of keys either at the top or bottom of the chamber, followed by the simultaneous depression of the opposite pair of lighted keys. Depression of a pair of keys extinguished the lights on that pair and illuminated the other pair of keys. This alternating response produced either a 50-Hz clicker or a 0.6-second presentation of a 6-Hz clicker. The 50-Hz clicker remained on until the food button was pressed; hence, it constituted a discriminative stimulus for food and is called  $S^D$ . The 6-Hz clicker occasioned no food; hence, it was a signal of the non-availability of food and is called  $S^\Delta$ . Food button responses in the absence of  $S^D$  had no consequences.

During the initial session the reinforcement schedule was changed to require more exercise responses to produce  $S^D$  and hence food availability. By the end of the first session, the ratio of responses to an  $S^D$  was increased to 10 to 1. However, this ratio varied randomly about a mean ratio of 10 to 1 and is therefore called a random ratio 10 (RR 10) schedule. That is, on the average, every 10 exercise responses resulted in the presence of  $S^D$ , and therefore food, if a food button response were made. Exercise responses not followed by  $S^D$  were followed by  $S^\Delta$ ; so, on the average, 9 out of 10 times  $S^\Delta$  occurred following an exercise response. Thus, the auditory stimulus following each exercise response allowed the animal to tell whether or not food was available and saved the animal the extra effort of pressing the food button when food was not available.

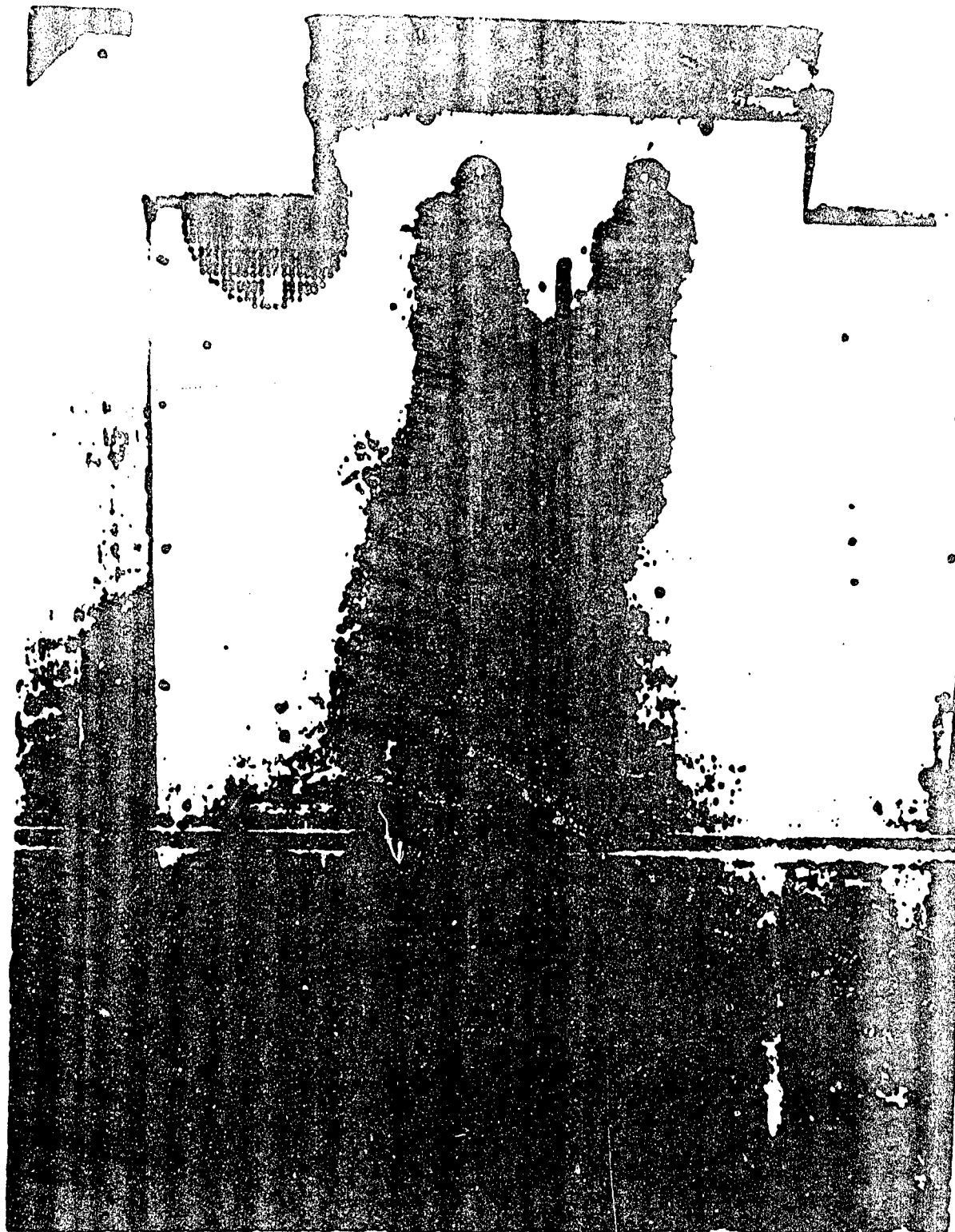


Figure 1

ZZI about to press the top response keys  
A small light can be seen behind each of the two keys

Sessions occurred 5 days per week. Early in the experiment each session was 4 hours long and water was continuously available. However, the animal began drinking excessively, became polydipsic, and the exercise response was not maintained very well. Therefore, water was removed and session length was reduced to 3 hours. The final 179 of 258 sessions were 3-hour sessions.

The following measures were obtained throughout the experiment: exercise response rate, post reinforcement pause, latency to press the food button following  $S^D$ , extra responses on the food button, reinforcement density, and general activity as measured by the photocell. The exercise response rate was calculated from top and bottom responses divided by the time elapsed from the first exercise response following a food button press to the next occurrence of  $S^D$ .

After behavior stabilized on the RR 10 schedule a RR 20 schedule was instituted to see the effects of reducing the frequency of food reinforcement. Other manipulations included the substitution of a brief  $S^D$  in place of  $S^\Delta$  to investigate the effects on the exercise response.

## RESULTS AND DISCUSSION

The exercise response typically consisted of a top key press followed by a bottom key press followed by a brief pause. The rates were relatively low in terms of responding on a simple manipulandum, but, considering the effort necessitated by the 30-inch distances between the pairs of keys, these rates might be considered to be quite high. Figure 2 illustrates typical cumulative records on the RR 10 and RR 20 schedules from 3-hour sessions. The random ratio schedule adequately maintained the exercise response throughout the session, especially on the RR 10 schedule as evidenced by the consistently high rates. The rates were relatively stable but tended to decrease during the terminal hour, particularly on the schedule with fewer reinforcements. Exercise response rates determined the density of reinforcement but were not entirely dependent on reinforcement density. When reinforcement density was decreased by placing the RR 20 schedule in effect, response rate decrement did not appear for seven to eight sessions. When reinforcement density was again increased, response rate increment lagged by about seven sessions.

The density of reinforcement also affected the post reinforcement pause. The post reinforcement pause was longer under the RR 10 schedule than under the RR 20 schedule. However, reinforcement latency, the latency to make a food button response following  $S^D$ , was not affected by the schedule change. This latency measure was very stable in most conditions and did not even seem to be affected by the session length. Reinforcement latencies tended to average about 1.0 second throughout a session with no consistent within-session trends.

Figure 2 also illustrates that as a daily session ended, the frequency of pausing between exercise response runs increased. However, the rates of the runs between pauses were not greatly affected. This break-and-run pattern was more evident under the RR 20 schedule.

221

RR20

250 RESPONSES

RR10

60 MINUTES

Figure 2

Consecutive response records of 221 illustrating typical performances under two directions of food reinforcement. Each record covers a 3-hour daily session. The pen runs at the end of an association and when the mouse is reinforced. Each record indicates presentation of the food. The pen was held down until a food button response was made.

A summary of the experimental manipulations and their effects on the exercise response rate is presented in Table I. The response rate shown is the median rate of the last three sessions under each of the schedules. The schedules are presented in chronological order. Table I shows that during the 4-hour sessions, response rates were at relatively low levels. This decrement was due to the development of polydipsia in the animal. Because of this development, it was impossible to adequately assess the effects of either the schedule change or the omission of  $S^{\Delta}$ . After 79 sessions, the water was removed, the session length was decreased to 3 hours, and the procedure was reinstituted. In the column designated by  $S^{\Delta}$ , IN indicates that  $S^{\Delta}$  was present following appropriate exercise responses and OUT indicates that  $S^{\Delta}$  was absent during these sessions. BRIEF  $S^D$  denotes those sessions when a 0.6-second presentation of  $S^D$  was given in place of  $S^{\Delta}$ . During the 3-hour sessions under the RR 10 schedule the response rates gradually increased, irrespective of the presence of  $S^{\Delta}$  during 65 sessions. Under the RR 20 schedule, with fewer reinforcements, the response rates decreased although they were higher in the absence of  $S^{\Delta}$ . When the brief  $S^D$  was given, the rates dropped to a very low level and even after nine sessions with  $S^{\Delta}$  replaced, had not recovered their previous levels. However, increasing the density of reinforcement by reinstituting the RR 10 schedule led to a recovery of response rates over the next eleven sessions. Later, the rate reached and surpassed its previous high following the last removal of  $S^{\Delta}$ . Table I illustrates that the exercise response rates were higher under the RR 10 schedule than under the RR 20 schedule and that they tended to be highest in the absence of  $S^{\Delta}$  and lowest when a brief  $S^D$  was used in place of  $S^{\Delta}$ .

The initial effect of  $S^{\Delta}$  removal on response rate is seen in Figure 3. The first  $S^{\Delta}$  on the abscissa of a frame designates the session preceding the change, and the third  $S^{\Delta}$  designates the initial session when  $S^{\Delta}$  was replaced. No  $S^{\Delta}$  denotes the first session when  $S^{\Delta}$  was removed.  $S^{\Delta}$  was removed and replaced three times, twice under the RR 10 schedule and once under the RR 20 schedule. The circles represent the first occasion, the triangles represent the second occasion, and the squares represent the third occasion.  $S^{\Delta}$  was not replaced the third time under RR 10 because the experiment was terminated. Under RR 20,  $S^{\Delta}$  was removed first during the 4-hour sessions and is shown merely to demonstrate that the effect took place even when behavior was disrupted by polydipsia. Figure 3 shows that whenever  $S^{\Delta}$  was removed, the initial effect was a decrement in exercise rate; but in the following sessions the rate recovered or surpassed its previous level. The terminal rates in each of these conditions, shown in Table I, confirm that the initial effects of  $S^{\Delta}$  removal were temporary because, in the absence of  $S^{\Delta}$ , the terminal rates were consistently higher than those preceding in the presence of  $S^{\Delta}$ . This was true except during the 4-hour sessions. If  $S^{\Delta}$  reinforced an exercise response, the rate in the absence of  $S^{\Delta}$  would have remained at the lower levels.

Changes in length of the post reinforcement pause also reflected the transient effects of  $S^{\Delta}$  removal. The post reinforcement pause increased during the first session with  $S^{\Delta}$  absent, but by the next session the pause had recovered its previous value. The difference was small and no longer than the average session-to-session changes. If  $S^{\Delta}$  had reinforcing qualities, the post reinforcement pause would have tended to remain at its increased

Table 1  
Summary of Average Terminal Response Rate As a  
Function of the Various Procedures

Schedule	Number of Sessions	Session Length (hours)	SA	Terminal Rate (rsp/min)
RR 10	20	4	IN	14.30
RR 20	30	"	IN	10.87
"	29	"	OUT	8.88
RR 10	39	3	IN	14.61
"	3	"	OUT	14.65
"	7	"	IN	15.16
"	6	"	OUT	17.32
"	10	"	IN	18.51
RR 20	32	"	IN	15.08
"	14	"	OUT	17.33
"	11	"	IN	14.66
"	31	"	BRIEF SD	12.33
"	9	"	IN	12.70
RR 10	11	"	IN	18.07
"	6	"	OUT	18.81

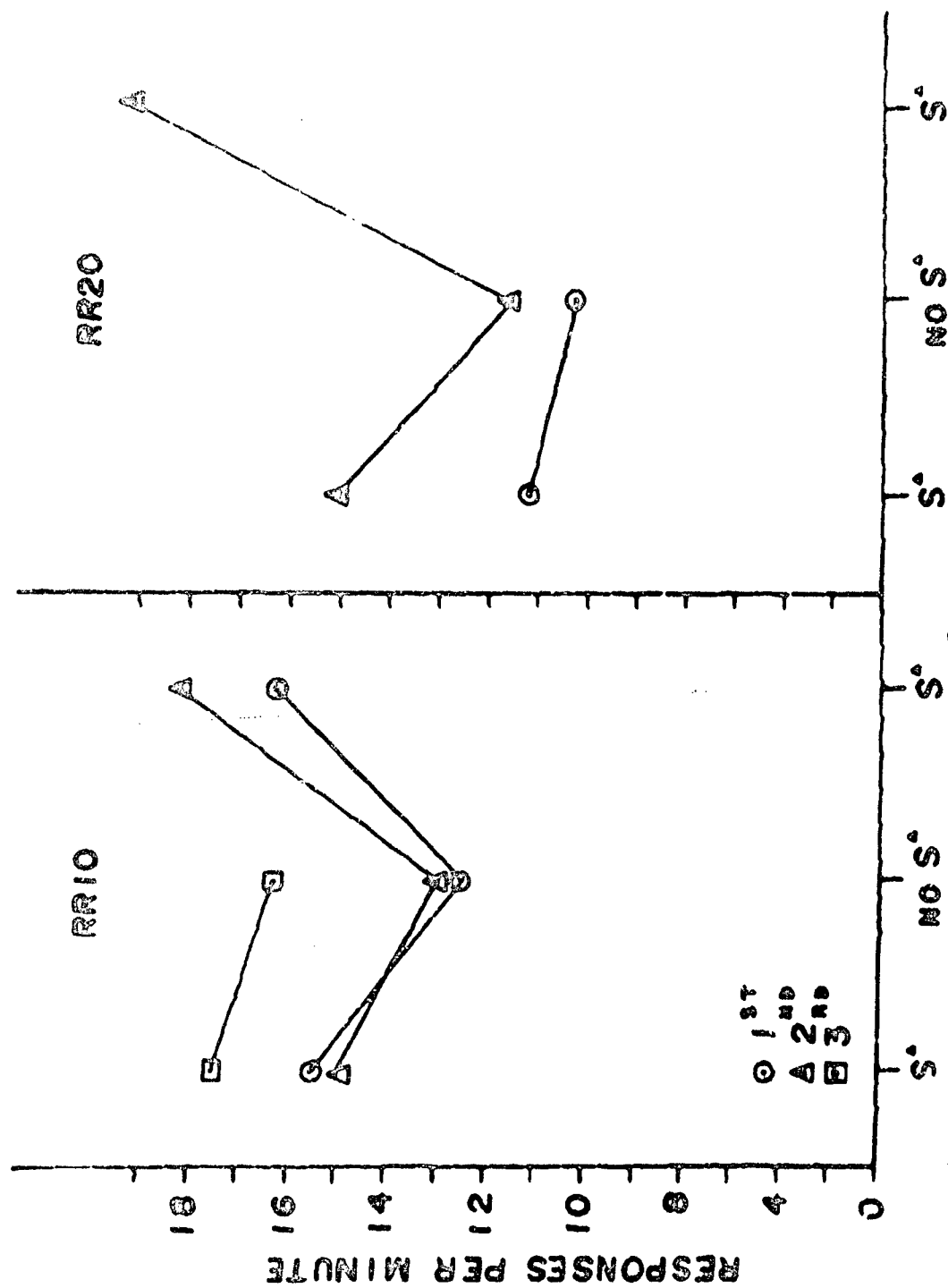


Figure 3

Mean exercise response rates under the two schedules as a function of the presence of S $\Delta$ . Symbols on the abscissa denote the presence or absence of S $\Delta$ . 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> denote the order of the repetitions when S $\Delta$  was removed and replaced. The data from the session prior to S $\Delta$  removal, (top from the session in which S $\Delta$  was initially removed, and finally from the session when S $\Delta$  was again replaced.

length as indicated by earlier investigations (2). Hence, in the present study, neither the response rate nor the post reinforcement pause provided indications that  $S^{\Delta}$  was a conditioned reinforcer.

The effect of  $S^{\Delta}$  appeared to be limited to its discriminative properties. Observation of 221 through the television monitor revealed that she would most often press the top keys, then the bottom keys, and then pause following  $S^{\Delta}$  stimulus. It was as though  $S^{\Delta}$  "paced" the exercise response. This topography was observed on numerous occasions. Figure 4 demonstrates 221's paced responding by an analysis of the time elapsed between each response. This measure is called the interresponse time interval (IRT) and reflects the various rates of responding within a specific period. The IRT distributions shown in Figure 4 were obtained from a session when the  $S^{\Delta}$  was absent during the first hour and present during the second hour. There were no IRT's of less than 0.5 second; so, the first interval in each frame is empty, and the last interval represents all IRT's in that interval or greater. The curves reflect the paced responding. Responses following a pause tended to take place in the 2 to 5 second range. The essential difference in the two distributions is that in the absence of  $S^{\Delta}$ , there were more IRT's in the 1-second or less range. If  $S^{\Delta}$  were a discriminative stimulus for a pause, then more IRT's would occur in the larger intervals and fewer in the short intervals, as seen in Figure 4. Yet, even in the absence of  $S^{\Delta}$  the bimodal curve was obtained. By this time in the experiment 120 sessions had passed, and the animal probably had developed a response topography that was impossible to eliminate completely. Nevertheless, this investigator feels that  $S^{\Delta}$  was responsible for establishing the paced response. This interpretation does not help to explain an initial decrement in rate when  $S^{\Delta}$  was removed. However, it does indicate that these brief pauses should eventually disappear in the absence of  $S^{\Delta}$  and that rates should increase as they occasionally did in the present experiment.

In many respects, the effects of replacing the  $S^{\Delta}$  with the same, only briefer, stimulus as  $S^D$ , were more definitive. As seen in Table I, under these conditions the rates decreased from their previous values. In fact, during the initial three or four sessions with the brief  $S^D$ , exercise responding almost was extinguished. The response decrement was produced because of the decrease in reinforcements. Reinforcements were not obtained because 221 responded to the initial brief  $S^D$  presentations by pushing the food button. The food-button responses in the presence of the brief  $S^D$  were not reinforced and rapidly extinguished. When the longer and actual  $S^D$  occurred, food button responses were not made; hence, reinforcement was not obtained and the exercise rate decreased. This chain of behavior resulted in the  $S^D$  remaining on throughout the rest of session the first time it happened. Gradually, the animal learned to wait until the stimulus had been on for an adequate period of time and then to respond on the food lever if the stimulus remained on. The record of the latency to push the food lever revealed that when the brief  $S^D$  was given in place of  $S^{\Delta}$ , the latency increased from an average of 1.1 seconds to 1.65 seconds and then returned to 1.1 seconds when the  $S^{\Delta}$  was reinstituted. At no other time during the experiment did this measure reliably change. Even reinforcement density had no effect. Obviously, during this manipulation, then, the animal discriminated the length of the stimulus and not its frequency. The brief  $S^D$  then had no prominent reinforcing characteristics and, in fact, acted as a punisher of 221's behavior. This finding

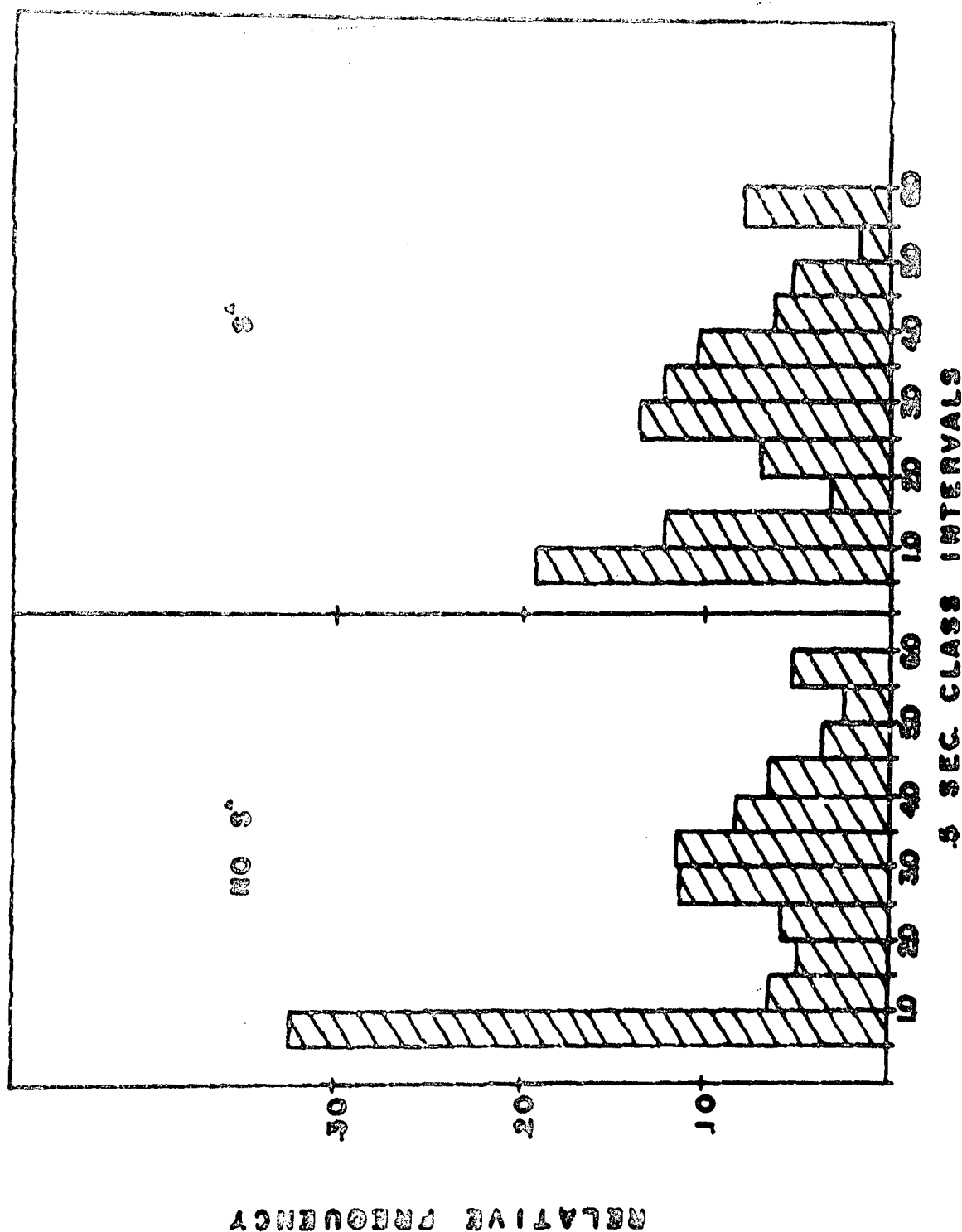


Figure 4

Sample distributions of intersession time intervals (RTI) in one session under the BR 10 schedule when SAs were absent during the first hour (No SA) and present during the second hour (SA). The abscissa designates 0.5-second class intervals by the small hash marks beneath the rectangles. Every two class intervals are numbered in units of seconds. The ordinate designates the proportion of the total occurrences that occupy a particular class interval. Over 900 responses occurred in each of the 2 hours that provided these distributions.

contradict the notion that stimuli contiguous with primary reinforcement invariably develop conditioned reinforcement attributes.

Other behavioral measures detected few consistent effects. 221's general activity tended to be greater when response rates were higher. Also, there was a tendency for extra responding on the food button when exercise rates were at a low rate. Extra food button responses consistently took place when the brief  $S^D$  was given in place of  $S^A$ .

## CONCLUSIONS

The exercise response as developed in the present study proved adequate to maintain long periods of cellistonic-type behavior. The facial validity of the technique is evident. The essential aspects of the technique were the use of an observing response procedure and the random ratio schedule. Although the presence of  $S^A$  seemed essential for the initial training of the exercise task, the study demonstrated that such a stimulus was not necessary for the maintenance of the exercise task and probably had the effect of retarding maximum response rates. On the other hand, the random ratio schedule prevented substantial pauses following a food reinforcement and inhibited other pauses. Continuous behavior, as obtained in the present experiment, could not have occurred without the use of a schedule similar to the random ratio.

At least in the present experiment, inserting the brief  $S^D$  stimulus demonstrated rather conclusively that any conditioning reinforcing value of a stimulus is outweighed by its discriminative properties. This probe provided support for the assumption that the  $S^A$  was also of limited reinforcing value.

The difference in exercise performance as a function of the frequency of reinforcement was in the expected direction and provided an indication of how much reinforcement would be needed to produce a given response output on similar tasks if used for future space projects.

During the entire 258 sessions 221 was in adequate health. The task itself certainly had no deleterious effects. Tasks similar to the present one should prove amenable to more direct physiological assessment of exercise. Telemetry devices could be attached to the animal to transmit heart beat and other relevant data. Currently our laboratory is evaluating physiological measurements using similar techniques.

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<p>A rhesus monkey was trained to perform a calisthenic task to obtain food and signals contiguous with food. The task was designed to produce continuous high effort behavior from the animal for long durations. The frequency of food reinforcements and related signals was varied to measure concomitant effects on exercise.</p> <p>Exercise was satisfactorily maintained for up to 3 hours. A reduction in the frequency of food reinforcement by 50 percent reduced exercise responding by less than 25 percent. Removal of signals associated with the absence of food had no significant effects and presentation of signals similar to the food-associated signal lowered the exercise response rate.</p>	